

## METHODS AND SYSTEMS FOR FLUID CONTROL IN MICROFLUIDIC DEVICES

### RELATED APPLICATIONS

[0001] This application claims priority to provisional application No. 60/307,638 filed Jul. 26, 2001, which application is incorporated herein in its entirety.

### FIELD OF THE INVENTION

[0002] The present invention relates to methods and components for manipulating samples using microfluidic systems. More particularly, the invention relates to microfluidic systems for concentrating particles, such as bacterial cells, entrained in a fluid.

### BACKGROUND

[0003] Microfluidic systems include devices with features having dimensions on the order of nanometers to 100s of  $\mu\text{m}$  that cooperate to perform various desired functions. In particular, micro fluidic devices perform material analysis and manipulation functions, such as to perform chemical or physical analyses.

[0004] One type of micro fluidic technology allows the manipulation of discrete amounts of materials, such as samples and reagents, in addition to continuous, flowing streams of material. Such devices are disclosed in, for example, U.S. Pat. No. 6,057,149, issued May 2, 2000 and titled "Microscale Devices And Reactions In Microscale Devices;" U.S. Pat. Nos. 6,048,734, issued Apr. 11, 2000 and titled "Thermal Microvalves in a Fluid Flow Method;" and 6,130,098, issued Oct. 10, 2000. In these devices, motive forces, such as gas pressure, are used as to urge material from one region of the device to another. For example, a sample can be pushed or drawn to a processing chamber where it is reacted with a reagent similarly moved into the chamber. Because each device can have many other chambers or channels that intersect with the processing chamber, valves can be used to isolate material in one region of the device from other regions of the device. An ideal valve would prevent leakage when closed and remain closed even when excess pressure acts upon the closed valve.

[0005] Citation or identification of any reference in this Section or any section of this application shall not be construed that such reference is available as prior art to the present invention.

### SUMMARY OF THE INVENTION

[0006] The present invention relates to a valve for use in a microfluidic system, comprising a substrate defining an upstream channel and a downstream channel joined by a passage, the passage comprising a first surface, and a thermally responsive substance (TRS) disposed, when the valve is in the closed state, to substantially obstruct the passage, wherein pressure present in the upstream channel urges at least a portion of the TRS against the first surface. Preferably, the passage defines a central axis and the first surface is disposed at an angle to the central axis. Upon opening the passage, at least a portion of TRS may melt and enter the downstream channel.

[0007] In one embodiment the valve further comprises a heat source in thermal contact with the TRS, wherein, upon actuation of the heat source, an opening motion of the TRS opens the passage.

[0008] The passage may further comprises a second surface disposed at a second angle to the central axis. At least a second portion of the TRS that obstructs the passage abuts the second surface. The first and second surfaces may protrude into the passage. The first and second surfaces form a restriction therebetween.

[0009] Another embodiment of the invention relates to a method for producing a valve for a microfluidic system, comprising providing a substrate defining a passage that joins an upstream and a downstream channel of the microfluidic system, the passage comprising a retaining surface and introducing a mass of temperature responsive material (TRS) into the passage, wherein, when the valve is in the closed state, pressure in the upstream channel urges the TRS against the retaining surface.

[0010] Yet another embodiment of the invention relates to a method for producing a valve for a microfluidic system, comprising providing a substrate defining a passage that joins an upstream and a downstream channel of the microfluidic system; and introducing a mass of temperature responsive material (TRS) into a reservoir channel adjacent the passage, wherein capillary action draws the TRS into the passage, and wherein a surface tension of the TRS substantially prevents the TRS in the passage from entering the upstream or downstream channel.

[0011] One embodiment of the invention relates to a valve for providing a passage between an upstream and a downstream channel of a microfluidic system, the valve comprising a temperature responsive substance (TRS), wherein, at a first temperature, the TRS is disposed to obstruct the passage, and wherein, at a second temperature, at least a portion of the (TRS) enters the downstream channel, thereby opening the passage.

[0012] At least about 75% of the TRS that obstructs the passage may enter the downstream channel upon the opening of the passage.

[0013] Another embodiment of the invention relates to a valve for providing a passage between upstream and downstream channels of a microfluidic system, comprising a temperature responsive substance (TRS) configured to substantially obstruct the passage and a heat source disposed in thermal contact with the (TRS), wherein, upon actuation of the heat source, at least a portion of the (TRS) enters the downstream channel, thereby opening the passage. Pressure present in the upstream channel preferably urges at least a portion of the TRS against the first surface.

[0014] Another embodiment of the invention relates to a microfluidic system, comprising a substrate defining a processing chamber, a source channel, and a downstream channel, the source channel joining the processing chamber at a first point and the downstream channel joining the processing chamber at a second point a thermally responsive substance (TRS) disposed to obstruct a passage between the processing chamber and downstream channel; and a heat source in thermal contact with the TRS, wherein, upon actuation of the heat source, at least a portion of the TRS enters the downstream channel, thereby opening the passage.

[0015] Another aspect of the invention relates to a valve for use in a microfluidic system, comprising a substrate defining an upstream channel and a downstream channel